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Canada Geodetic Survey

DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister

W. W. CORY, C.M.G., Deputy Minister

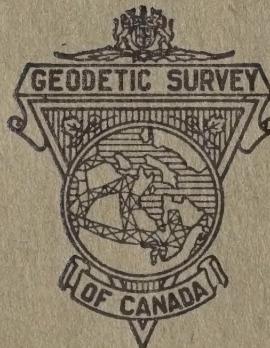
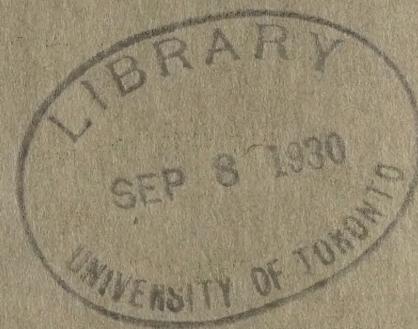
J. D. CRAIG,  
Director General of Surveys

NOEL J. OGILVIE, Director  
Geodetic Survey of Canada

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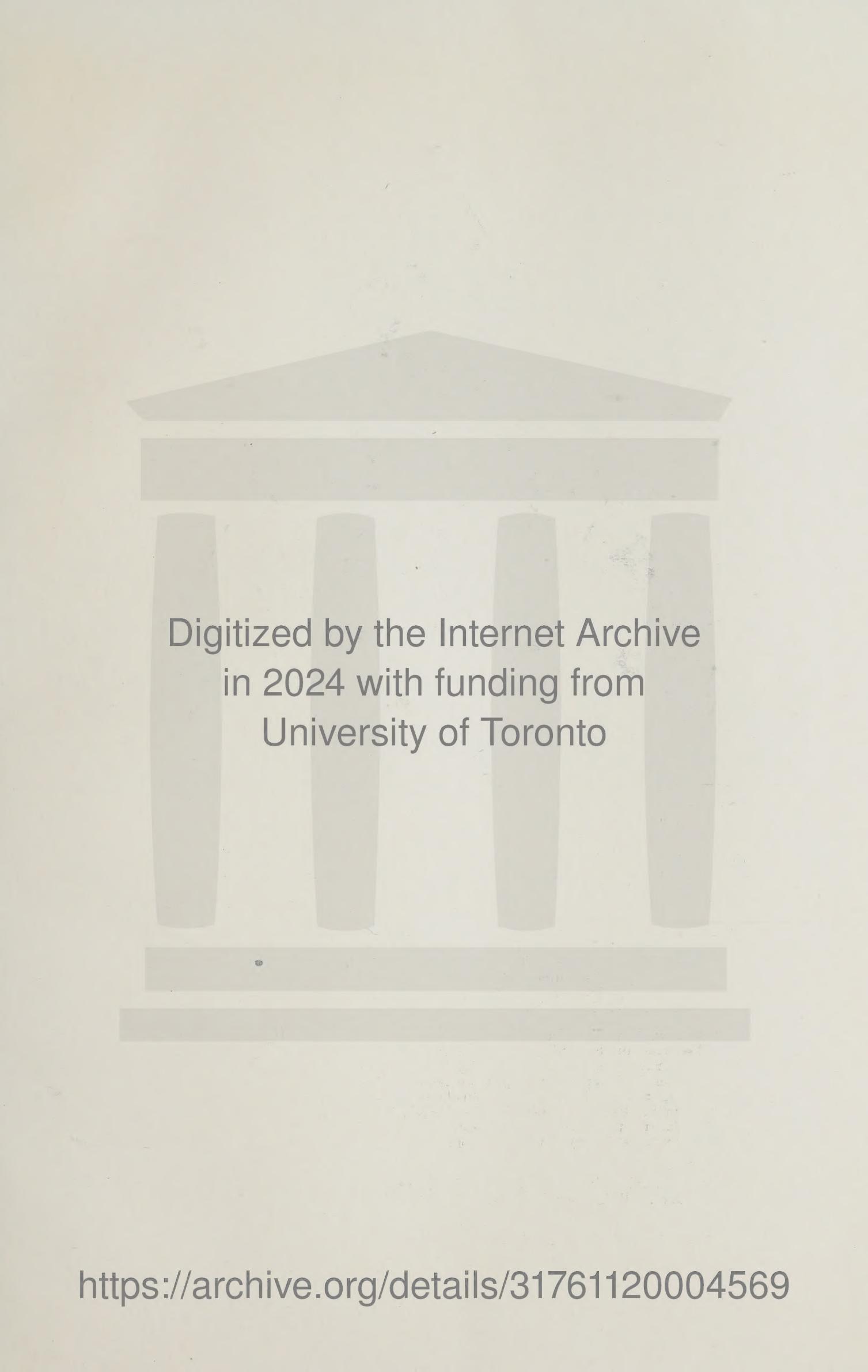
ANNUAL REPORT  
OF THE DIRECTOR  
OF THE  
GEODETIC SURVEY OF CANADA  
FOR THE  
FISCAL YEAR ENDED MARCH 31, 1929

1928/29



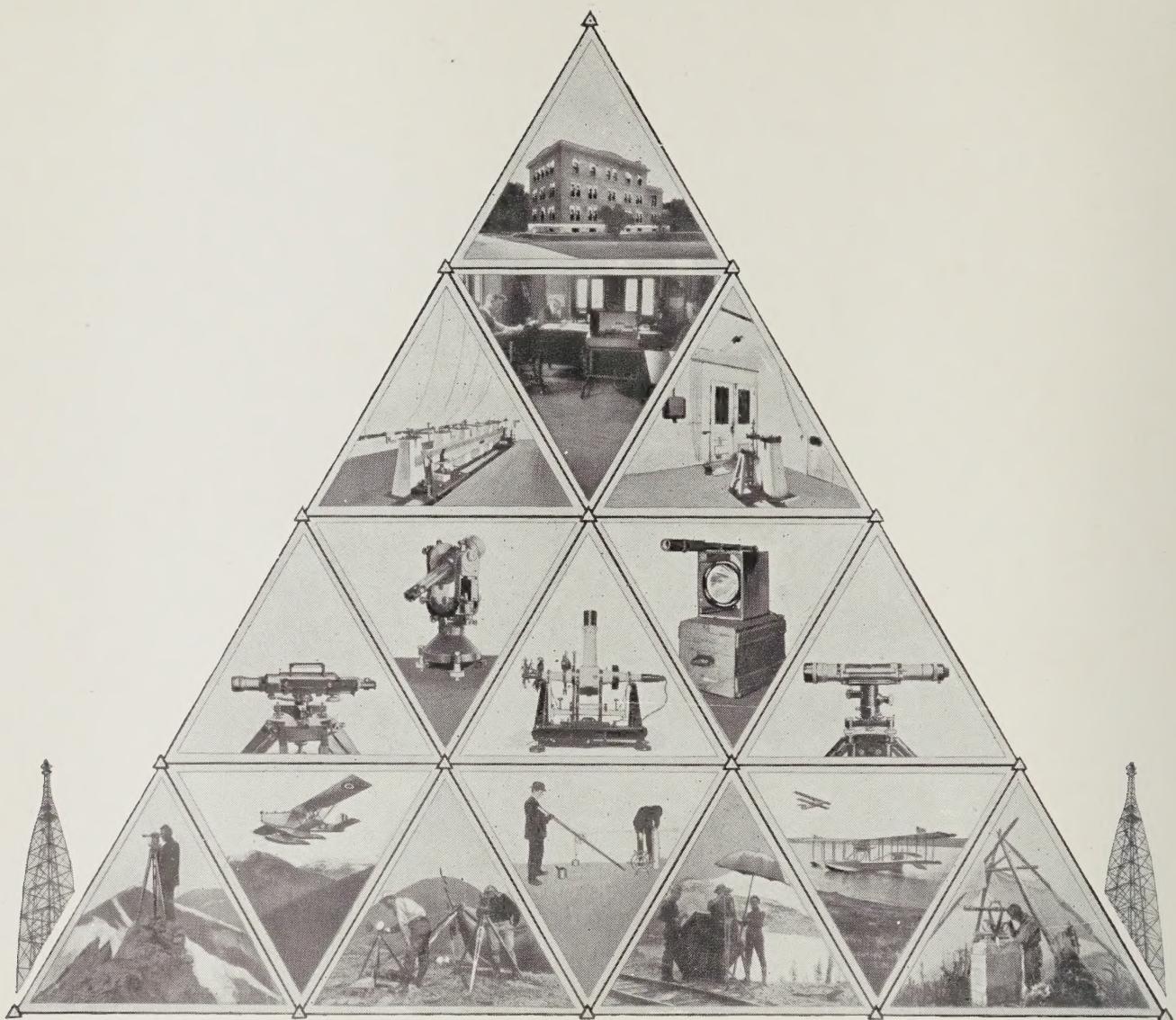
OTTAWA  
F. A. ACLAND  
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY  
1920





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Top—Geodetic Survey Building at Ottawa.

Second row, left to right—

North end of Standards building, showing five-meter bar apparatus.

Office of Precise Level Adjusting Division.

Fiducial point at south end of 50-meter comparator, in Standards building.

Third row, left to right—

Precise Level, U.S.C. & G.S. Pattern.

Latest Model Primary Triangulation Model theodolite.

Latest Model Astronomical Transit.

Electric Signal Lamp for Primary Triangulation.

Precise Level, Zeiss Model.

Bottom row, left to right—

Observing on Secondary Triangulation.

Photographic and Transport Hydroplane, Canadian model.

Sending instructions to light keepers by heliograph.

Setting rear end of tape in Baseline measurement.

Observing Precise Levels in the Yukon Territory.

A Transport Hydroplane at rest.

Observing Primary Triangulation.

On flanks—

Triangulation Tower near Chatham, Ont., with Lamp-stand extended 37 feet. Height of Lamp-stand, 147 feet.

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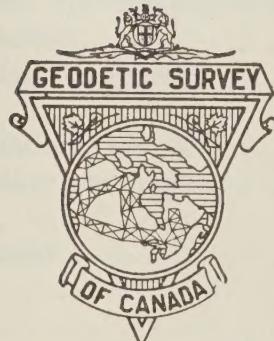
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## ANNUAL REPORT OF THE DIRECTOR OF THE GEODETIC SURVEY OF CANADA FOR THE FISCAL YEAR ENDED MARCH 31, 1929



OTTAWA  
F. A. ACLAND  
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY  
1930



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# THE GEODETIC SURVEY OF CANADA

## ANNUAL REPORT OF THE DIRECTOR, NOEL J. OGILVIE

### INTRODUCTION

Both the field and the office work in the program of the Geodetic Survey of Canada were successfully carried out during the fiscal year ended March 31, 1929.

Field parties operated in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and New Brunswick.

The following is a tabular statement of the field work accomplished:—

Operations	1928 season		Total to date
	Miles	Miles	
Primary triangulation, axial length.....	751	6,155	
Secondary triangulation, axial length.....		874	
Reconnaissance completed.....	875		
Precise traverse.....	29	409	
Precise levelling.....	448	23,823	
Secondary levelling.....	403	9,833	
		Number	Number
Standard precise bench marks.....	249	8,195	
“ secondary bench marks.....	195	3,166	
Fundamental bench marks.....	14	67	
Astronomical stations.....	13	32	
Laplace stations.....	6	46	
Base lines.....	1	26	

As in previous years, this office has carried on the technical operations required to furnish geodetic control data for geographic positions and elevations above sea level in response to requests received in increased numbers from surveyors, engineers, scientists and others. A large number of recent refinements in elevations of precise level bench marks were printed and distributed, and others are in course of preparation.

Considerable material for the Fourth General Conference of the International Geodetic and Geophysical Union to be held at Stockholm, Sweden, in 1930 has received attention and is being prepared for presentation.

The divisions of Mathematical Research, Triangulation Adjustments and Precisions and of Precise Level Adjustments and Precisions have assisted materially in the development of special methods for the accurate control of geodetic work when such has to be extended over the long distances which are unavoidable in a country as large as Canada.

The precise traverse has again proved an economical substitute for triangulation where the latter, owing to the nature of the terrain, would be unduly costly. In this connection the value of recent mathematical investigation as to the conformation of the traverse to the shape of the earth should be noted.

The study of new types of field instruments has also resulted in important advantages to the survey, the use of these instruments having greatly increased the efficiency of the parties by whom they were used.

The determination by means of wireless signals of longitude at points which are essential in the program of the Geodetic Survey, but which are distant from telegraph lines, has been made with satisfactory results as in previous years.

Test aeroplane flights were made to determine the extent to which aviation may be advantageous in triangulation reconnaissance.

Six new publications of the Geodetic Survey of Canada were printed and are being distributed. Owing to an increasing demand, larger editions than formerly have been found necessary.

### TRIANGULATION

Field work extending the triangulation of the Geodetic Survey of Canada was successfully carried on during the season.

Parties operating in some northerly areas experienced adverse weather conditions, but in spite of this fact the number of angular measurements completed in 1928 exceeded those of the best season on record (1925) by seventeen per cent, and those of the rainy season of 1927 by sixty-five per cent. This increase in the number of stations completed is in no small part due to the use of the new type of theodolite with which all parties have been equipped. These theodolites combine the advantages of extreme lightness for packing and great speed in operation, and it is considered that the instruments have more than paid for themselves in the increased work accomplished.

The weight of this new type is less than half that of any previously used. The advantage due to this fact effects an important saving of time in rough country where considerable back-packing is necessary, a condition which exists in a number of the areas in which primary triangulation is being carried on in Canada. The greater speed of operation of the new instrument as compared with the old is a factor of considerable importance in obtaining angular measurements on primary work, enabling a greater number of measurements to be made during short intervals of good weather which may occur in a prevailingly unfavourable period. Where transportation facilities are good, it is sometimes possible to observe at two stations in a single night, something which could not have been accomplished with the older type of theodolite under any circumstances.

A statement of the progress of the field work in 1928 is given in tabular form on page 5.

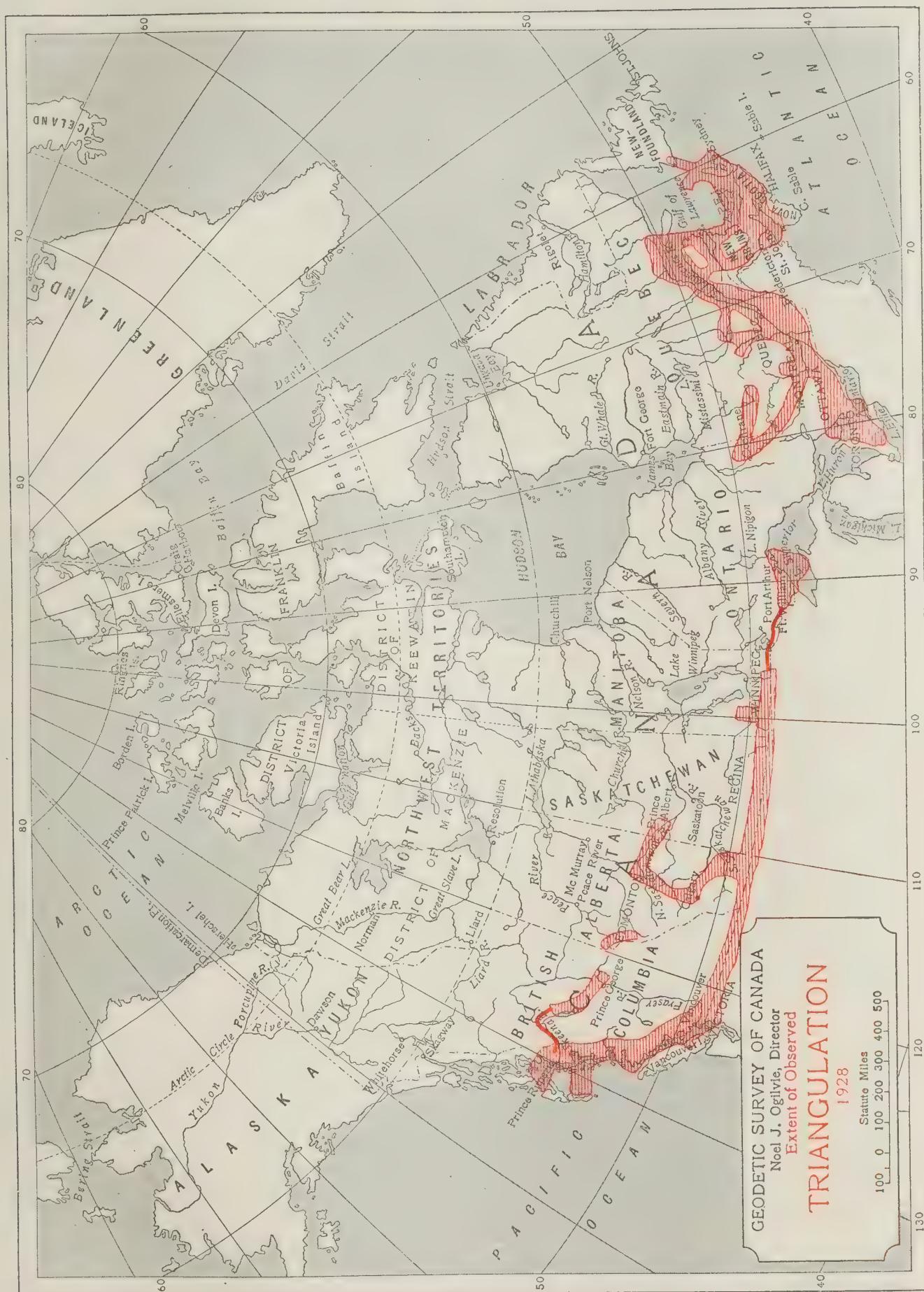
### TRIANGULATION RECONNAISSANCE BY AEROPLANE

In 1921 the officer of the Geodetic Survey in charge of triangulation reconnaissance in the Fraser River watershed northeast of Vancouver, B.C., was able, through the co-operation of the Royal Canadian Air Force to carry out part of his work by aeroplane.\* This was purely an experiment, and so far as is known, was the first time the aeroplane had been used for this purpose.

While the advantages of the method in mountainous country have thus been known for several years its application to flatter country has only recently been realized, and test flights made in February and March, 1929, by officials of the Geodetic Survey of Canada, again in co-operation with the Royal Canadian Air force, demonstrated that the aeroplane is an important aid in reconnaissance work, and that, in suitable types of country, satisfactory, economical and exceedingly rapid reconnaissance can be performed.

The safe use of single motored planes for triangulation reconnaissance is limited to country abounding in lakes or large rivers where occasional low flying can be practised, or to very hilly country interspersed with landing places

\*Annual Report of the Director, Geodetic Survey of Canada, 1922 pp. 30-37.





where higher flying is suitable to the operation. The preliminary selection of hills must be made from approximately the height of the tops of these hills, so that for flat unwatered bush country single motored planes are not suited, as very low flying would be hazardous. Fortunately much of the country in which future triangulation will be performed in Canada abounds in lakes and fairly large rivers and in such districts present type planes can be very satisfactorily employed for reconnaissance and there is no doubt but that much of the future triangulation reconnaissance in Canada, as well as the transportation of parties in certain areas will be done by aeroplane.

#### TRIANGULATION IN NORTHERN BRITISH COLUMBIA

Tringulation operations in British Columbia during 1928 were a continuation of the operation commenced in 1925—the laying down of primary control eastward from the Pacific coast at Prince Rupert, following the Canadian National railway across the province via the Yellowhead pass and connecting with the Alberta triangulation at Jasper. A precise traverse has been executed along the railway as far as Smithers, a distance of 200 miles.

At Prince George the trans-provincial net has been temporarily discontinued and a triangulation net connecting that point with Vancouver will be the next work undertaken. Reconnaissance for the selection of stations has been started from both ends. The necessary preparation of stations was undertaken at the Vancouver end. In 1929 the parties which have been working west of Prince George will be moved to Vancouver, and this net will be proceeded with from the south end. The completion of this net to Prince George will require operations for two or three seasons.

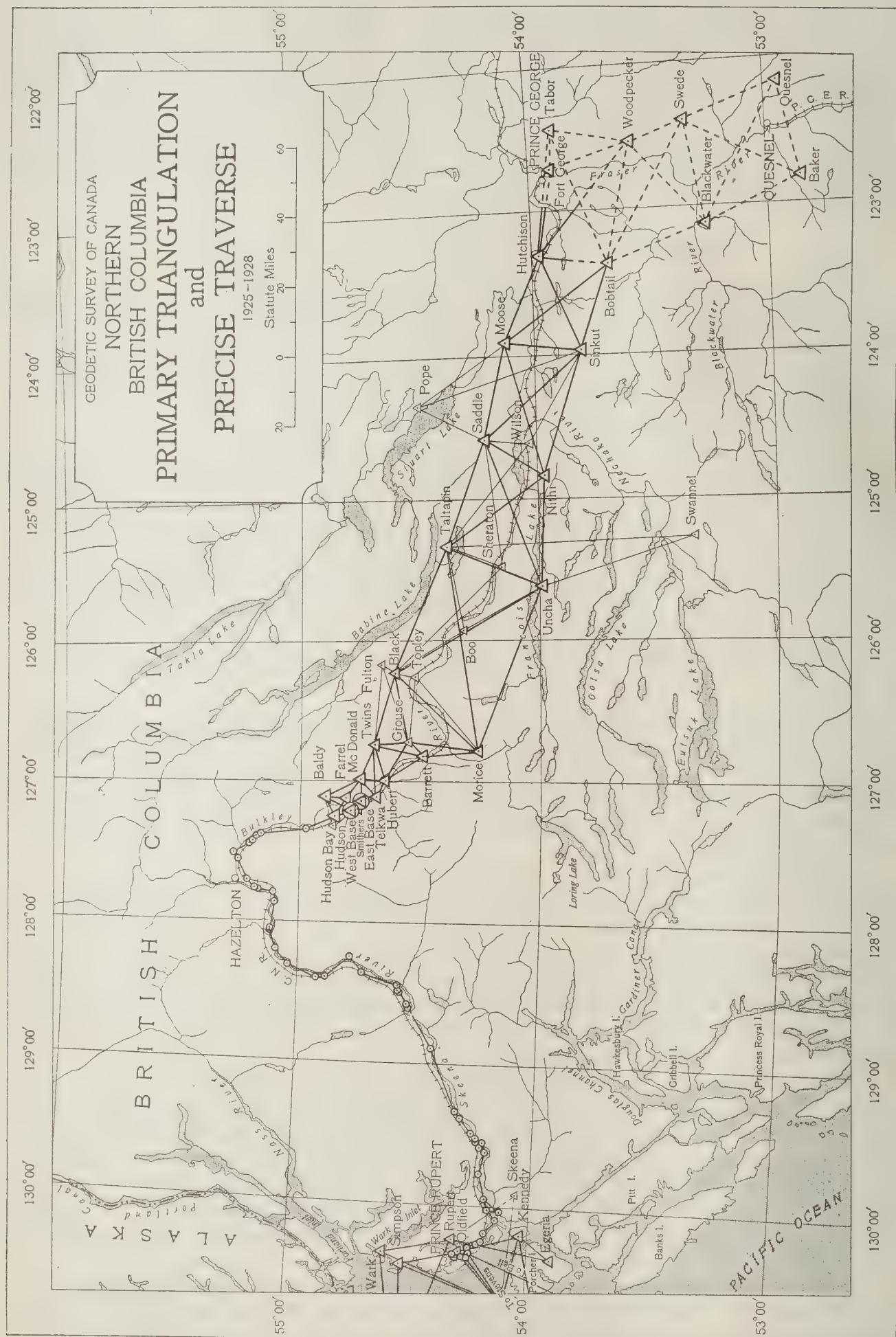
Details of the 1928 operations follow, and a sketch of this work appears on page 8.

*Results Obtained.*—*Reconnaissance:* 12 primary and 3 secondary intersection stations selected; axial length of net, 170 miles. *Station Preparation:* The above 3 secondary stations and 10 of the primary stations monumented and prepared for angular measurements. *Angular Measurements:* 11 primary and 7 intersection stations completed; axial length of net, 142 miles; area covered, 3,250 square miles.

Fair progress was made, considering the usual weather handicaps, the shortness of the season and difficult transportation conditions. The first half of June was much drier than usual resulting in some early bush fires. Then followed two weeks of wet weather with clouds on the mountains which completely obscured the triangulation stations. From the middle of July to the close of the season excellent observing conditions prevailed and satisfactory progress was made. The season's work was begun during the last week in May and finished the first week of September.

The personal for the season's work was organized into three parties. The District Engineer, with one assistant, did the reconnaissance in addition to his other duties. This started at the east end of Francois lake and concluded in the vicinity of Quesnel. The triangulation net follows the railway and highway which parallel each other here, and, as far as possible, stations were located along them to avoid making long trails. In locating the points so as to give the required mathematical strength to the figures, the proximity of a station to a road or trail was always considered.

The station preparation party was composed of an engineer's assistant and four labourers. Their work was to make trails, mark the stations and clear whatever vistas were necessary. Trials varied from two to eight miles in length



and these were cleared out and blazed. Nearly all the stations were marked with the regulation bronze tablet leaded into rock. Most of the mountains were timbered on the summits and it was necessary to clear vistas.

There were two observing parties and four pairs of lightkeepers. Operations were begun near Quick and finished near Prince George. The lines averaged thirty-five miles in length and all the observing was done at night. The new type five-inch theodolites were used and proved highly satisfactory.

Transportation is one of the chief problems of field parties in this section of the country. The main highway follows closely the line of the railway with occasional side roads leading in to scattered settlements. The side roads are not in good condition and are often impassable. Light trucks were used on the main road and on passable portions of the side roads; in other portions wagons or pack horses were employed and lastly backpacking was resorted to. As the utmost reduction of weight is of prime importance in the latter method of transportation the small signal lamps recently provided and the light theodolites proved a great advantage.

#### PRIMARY TRIANGULATION IN ALBERTA AND SASKATCHEWAN

The 1928 triangulation in these provinces was a continuation of the 1927 operations. Triangulation had been laid down along the 49th Parallel International Boundary by co-operative action of the geodetic surveys of Canada and the United States, and from a line of this net in the Cypress Hills, about longitude  $111^{\circ}$ , an extension was made northerly and westerly through Medicine Hat to Calgary. At this point a connection with the British Columbia nets through the mountains was included as a part of the triangulation program. From Calgary the triangulation runs directly north to Edmonton where it has been decided to make another connection with the British Columbia work via Yellowhead pass. Preliminary work on this connection reached Edson, Alberta, about 100 miles west of Edmonton.

Though several nets northward from Edmonton have been planned, no work has so far been done on them.

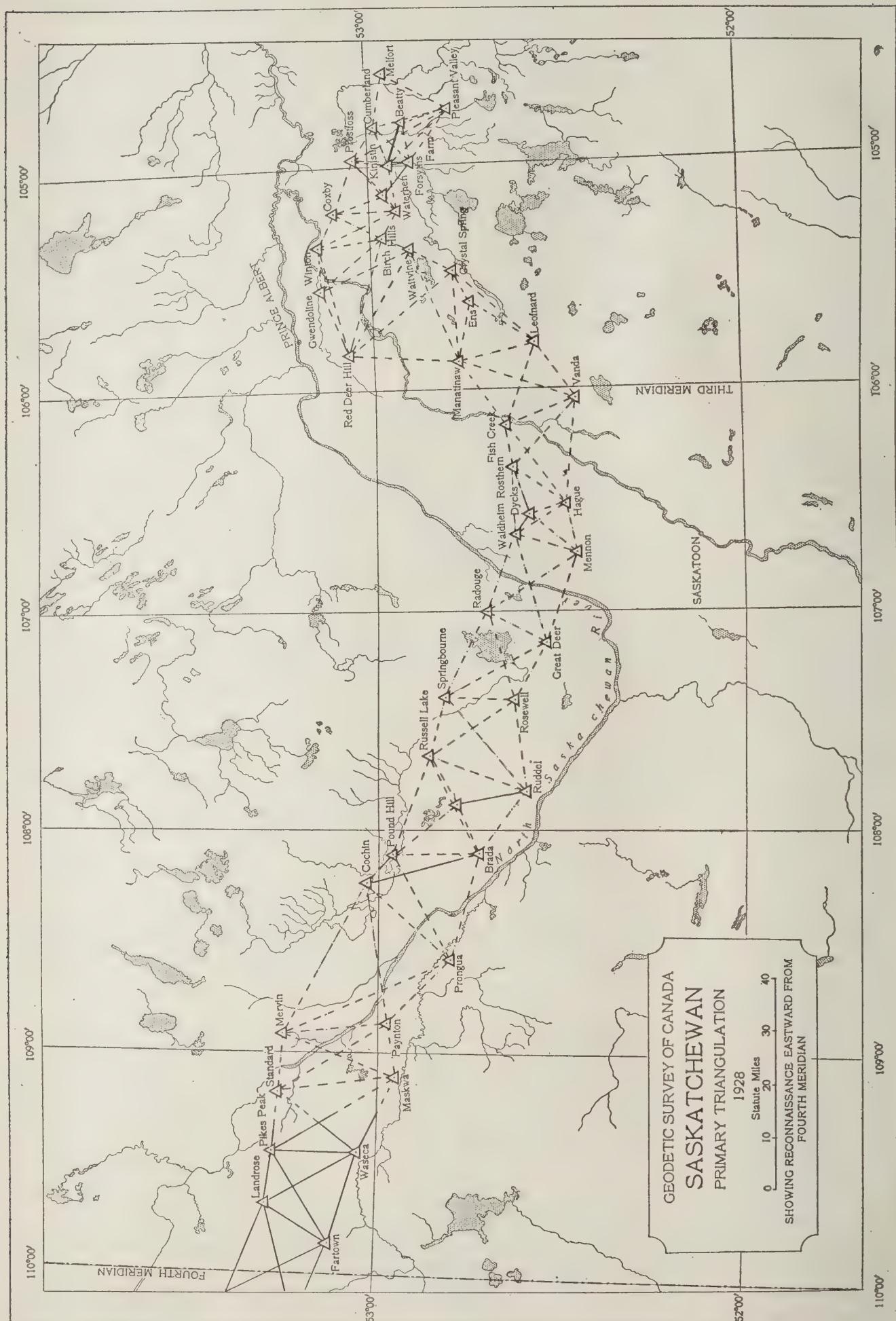
Eastward from Edmonton a net has been laid down along the general route of the Canadian National Railways through Lloydminster, Alberta, and Battleford, Saskatchewan. At a point just north of Saskatoon this scheme turns northward to the vicinity of Prince Albert, thence eastward to Melfort, Saskatchewan, where the season's operations ended.

Projected nets in these provinces include one from Melfort, Sask., south-eastward to connect with the Brandon, Man., net and through this to the 49th Parallel International Boundary, thus forming a large circuit which will probably be further divided by one or more cross chains to ensure the necessary accuracy of the triangulation.

Plans have been made for the extension of triangulation which will be of much value in controlling surveys necessary in the development of the recreation grounds and the mineralized country north of Prince Albert, Sask. Nets will be laid out by aeroplane in this district including Prince Albert national park and the mining areas in the vicinity of Rotten Stone lake.

Details of the 1928 operations follow. A sketch of the work accomplished appears on page 10.

*Results Obtained.*—*Reconnaissance*: 37 stations and one base line selected; axial length of net, 200 miles; area covered, 2,941 square miles. *Station Preparation*: 33 standard piers and 12 towers built; distance covered, 200 miles. *Angular Measurement*: 53 primary and 11 supplementary stations completed; connections made with 42 land survey corners; axial length of net, 250 miles; area covered, 3,445 square miles.



The reconnaissance, or selection of stations, which was carried on by one engineer and his assistant, was commenced near North Battleford, Sask., and carried eastward to Wakaw, thence northward to Prince Albert and eastward to Melfort, Sask.

One station preparation party, consisting of a foreman and five labourers, followed the reconnaissance party, permanently monumented all stations, built towers where necessary and prepared the stations for occupation by the angular measurement party. This party commenced work near Mundare, Alta., about 50 miles east of Edmonton, and continued east as far as North Battleford, Sask.

Angular measurements were made by a party consisting of an engineer, one assistant and five men. This party followed the station preparation party, and started operations for the season at a point near Red Deer, Alta., about 75 miles south of Edmonton. It worked north to Edmonton then easterly as far as Lashburn, Sask.

A number of points were established in and close to the city of Edmonton to serve as a basis for city triangulation. These consisted of three primary stations close to the city and two secondary stations in the city and suburbs, one on the roof of the government elevator and the other just north of the suburb of North Edmonton. In addition two supplementary stations were established, one on the Civic Block to ascertain the position of the Edmonton fundamental bench mark established by the Geodetic Survey of Canada and the other on St. Stephen's College to ascertain the position of a pier built by the University of Alberta in the college grounds.

Wet weather in June hampered operations, but for the remainder of the season excellent progress was made. Conditions were such that no delays occurred on account of transportation. To further facilitate this the light type of theodolite was used. This fact accounted for the following policy which was adopted in making angular measurements in this district: The measurements were completed at each station in a single night wherever possible; If the errors indicated by the angle and side equation tests did not fall within the prescribed limits set for primary work, the re-observing necessary to bring them within those limits was done on the same night as direction measurements at another primary station were made. For example, in June, 1928, seventeen stations were observed, five of which were re-occupied to measure one or more erroneous directions, on the only seventeen nights on which observing was possible.

The above operations demonstrated the fact that lightness for transportation and speed of operation of the new type of theodolite are real factors in speeding up angular measurements, and that these advantages have not been secured at any sacrifice of accuracy. This is amply indicated by comparing the triangle closing errors of the 1928 work with those of the previous season in which older types of theodolites were employed. The average error of closure of 104 triangles, the angles of which were measured with the older type theodolites was 0.891 second, while that of 130 triangles measured with the new type of theodolite in 1928 was 0.855 second.

#### PRIMARY TRIANGULATION AND PRECISE TRAVERSE IN NORTHERN ONTARIO

To understand the significance of the 1928 operations in northern Ontario it is necessary to explain the plans made for primary control which will be undertaken in the next few years in this area. A study of the map of eastern Canada, inside the back cover of this report, will help to make these plans clear.

A 375-mile net has been completed from Ottawa northwest almost to Cochrane, Ont., following the Ottawa river and the Timiskaming and Northern Ontario railway. From this net it was formerly intended to run a primary triangulation net westward across the province from Cochrane following the Canadian National railway, also a net to James bay following the Timiskaming and Northern Ontario extension.

The flat country north and west of Cochrane forced a change of plans. This area is ideal for precise traverse along a railway but quite unsuitable for economical triangulation operations. For this reason the main east and west transprovincial net had to be swung south of this flat area, and was started west from Porquis Junction passing through the Timmins and Kamiscotia mining areas to the Sudbury-Nakina line of the Canadian National Railways. This line will be followed to Nakina, thence westerly across the province. In the meantime a precise traverse was run north as far as Cochrane and will be continued north towards James bay, also westerly towards Nakina. These traverses are being taken in hand in the parts of the season in which bad roads make for slow progress of the triangulation in the Sudbury and other northern Ontario areas.

Details of the 1928 operations follow.

*Results obtained.*—*Reconnaissance:* 15 primary and 6 supplementary stations selected; axial length of nets, 88 miles; area covered, 1,740 square miles. *Station Preparation:* 12 triangulation and 9 traverse stations prepared, at 8 of which towers were built. *Angular Measurements:* 16 primary and 10 supplementary stations completed; axial length of net, 100 miles; area covered 2,100 square miles. *Precise Traverse:* 18 azimuth stations and 15 traverse stations (unmarked); length of traverse, 29 miles.

The entire season, with the exception of two weeks in August, was the wettest experienced in survey operations in northern Ontario. In addition to making transportation very difficult, this decreased the results of the season's operations, as the proportion of time lost due to rain was very high.

Reconnaissance for selection of triangulation stations was carried on in two areas, westerly from North Bay to the vicinity of Sudbury, and southwesterly from the Timmins and Kamiscotia mining district to the Canadian National railway in the vicinity of Gogama. The work in the North Bay-Sunbury area reached the eastern edge of the Sudbury mining district in the latter part of July when the reconnaissance engineer moved to the Timmins area. In the area southwest of Timmins canoe transport was used exclusively as there were no roads between the section immediately around Timmins and the railway line south of Foley yet. This country was flooded to such an extent in the early part of the season that reconnaissance operations were almost impossible until late in July. Operations in this area were discontinued on September 27.

The greater part of the season's work for the station preparation party was spent in the district between Mattawa and the westerly end of lake Nipissing. High towers were necessary at most of the stations in this district and suitable timber had to be obtained at outside points as it was not available close to the stations.

Angular measurements were started at Monteith in the clay belt south of Cochrane and carried northerly to Nellie lake, thence easterly across lake Abitibi to a point a little east of the Ontario-Quebec boundary. The axial length of this net is about 60 miles. Angular measurements in this district were completed on August 10, and the party moved south to Mattawa, continuing the triangulation westerly in the more settled country from Mattawa to North Bay. The stations were located on both sides of the valley of the Mattawa river as far as Callendar and from here westerly on each side of lake Nipissing. Angular measurements were discontinued for the season on October 15.

Near the last of the season precise traverse was carried on in the vicinity of Cochrane, a district in which the terrain is suitable for precise traverse and unfavourable for triangulation. The country is very level and triangulation would be very slow and costly on account of the necessity of high towers and the

absence of roads in the wooded portions of a country where spruce muskeg abounds. Moreover there is here a railway line over which a traverse can be carried.

The precise traverse was started from triangulation station Calvert and carried north along the main line of the Timiskaming and Northern Ontario railway to its junction with the Canadian National railway just east of Cochrane, then westerly along the Canadian National railway to a point  $2\frac{1}{2}$  miles west of Cochrane.

#### PRIMARY TRIANGULATION IN WESTERN QUEBEC

Primary triangulation in the large district westerly from Quebec city to the Quebec-Ontario boundary was carried on in three areas in 1928. Reconnaissance, station preparation and angular measurements were carried on through the Rouyn and Amos mining area and eastward along transcontinental line of the Canadian National Railways. Reconnaissance was laid down connecting this work with the net extending westward from La Tuque and with that extending along the Gatineau River valley. The sketch on page 14 shows the work accomplished in these areas. A study of the map at the end of this report shows that this triangulation along the Canadian National railway, when completed in 1930 or 1931 will close a 900-mile loop which is subdivided by the Gatineau net. These nets will form a strong basis for triangulation nets northward to Hudson bay and to the Chibougamau mining district. Preliminary work on the latter will be started while the above work is being completed.

#### ROUYN-SENNETERRE NET

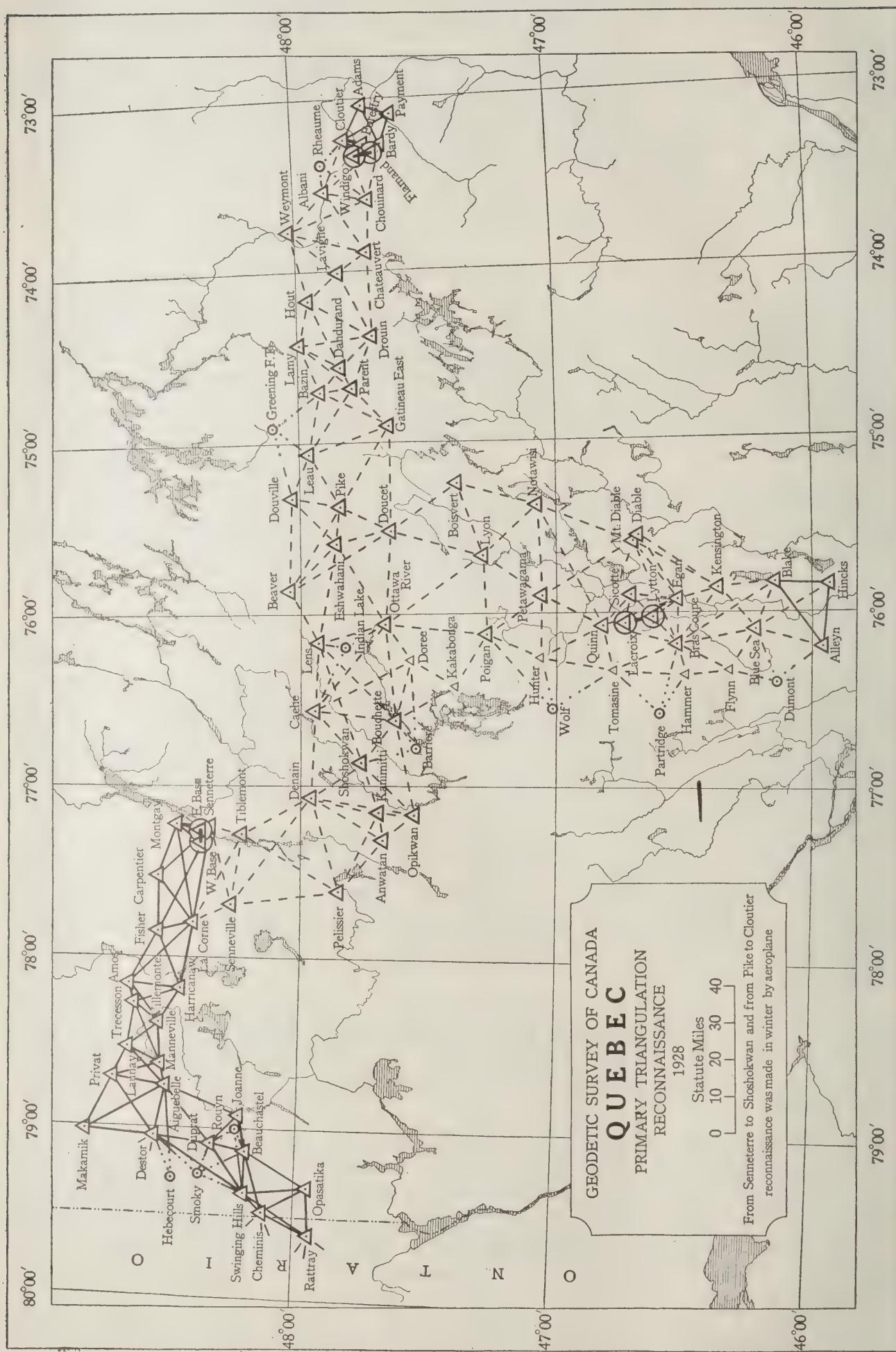
*Results Obtained.*—*Reconnaissance:* 13 primary and 1 secondary station, also one base line and two Laplace stations selected; axial length of net, 70 miles. *Station Preparation:* 16 stations monumented and prepared for angle measurement, on 12 of which towers of an average height of 20 feet were built. *Angle Measurement:* 23 primary and 6 intersection stations completed; axial length of net, 130 miles; area, 1,600 square miles.

This net is an extension from the line Rattray-Cheminis in the Ottawa river net near the Ontario-Quebec boundary. The general direction of its course is east as far as Rouyn, a distance of about 30 miles, thence north about 35 miles along the Canadian National Railway branch line to Taschereau on the transcontinental line, thence east along the latter line to Senneterre, a further distance of about 65 miles.

A base line of slightly over four kilometres was selected and measured at Senneterre. Two Laplace points were selected, one at Macamic, about half way between adjacent base lines, and one at the west end of the Senneterre base line. The astronomical observations at these points will be completed at the beginning of the 1929 season.

At the stations on the Rouyn section of the net the usual practice of observing at night with electric lamp signals was employed. On the rest of the net observations were made during the day, and this practice materially aided in speeding up the work. The signals used during the day consisted of two pieces of white cotton, each six feet square, set at right angles to each other on an upright pole which was mounted on the top of the tower directly over the centre of the tripod.

An unusual absence of haze during the season, due to the constant rainy weather which kept the air clear proved an advantage in daylight observing. Lines up to 30 miles in length were observed in this way.



Two intersection stations, Smoky and Hebecourt were located in the Duparquet Lake area for the use of mapping parties of the Geological Survey. These were monumented in the same manner as the primary stations. Connections were made to three points on the Geological Survey traverse which was run along the transcontinental line of the Canadian National Railways from the Ontario-Quebec Interprovincial Boundary east of Senneterre.

While weather conditions were fairly good in July and August, rain interfered abnormally with the progress of the season's work. In the Rouyn section it rained on some part of every day in June, September and October.

#### GATINEAU WATERSHED NET

In the northern Gatineau watershed reconnaissance was continued during the season. Excessive rain, together with difficulties of transportation, impeded progress to a great extent. This work was carried on as a co-operative undertaking with a large pulp and paper company, which found that the triangulation stations afforded the best sites for fire detection stations. Eighty-foot steel lookout towers are being built by the company at almost all of the sites selected, to which trails are being cut and telephone lines strung, all of which will prove of material advantage in the preparation and occupation of geodetic stations in this district.

Four stations were also permanently monumented, and an observing tower was built at one station.

*Results Obtained.—Reconnaissance:* 10 primary and 4 supplementary stations selected; axial length, 55 miles; area covered, 2,300 square miles. *Station Preparation:* 4 stations prepared, at one of which a 20-foot tower was built.

Work on the triangulation in the Rouyn-Senneterre area and the Upper Gatineau districts was discontinued for the season in October. Between the two nets there remained a gap about 75 miles in length, while between the Upper Gatineau net and the completed triangulation just west of La Tuque, Quebec, there remained another gap 115 miles in length. These gaps provided a suitable opportunity to test the usefulness of the aeroplane for reconnaissance or selection of triangulation station sites. The areas were within two hours flying distance of Ottawa and on account of numerous lakes and fairly large rivers low flying can be done in safety.

Seventeen flying hours—exclusive of the time taken in going to and returning from the area—were spent in the reconnaissance. The cost of the operation, at commercial flying rates, was less than half what it would have been had the conventional ground methods been employed. The work was completed in ten days whereas ground methods would have occupied at least two seasons.

The intervisibility of a few of the lines could only be settled by actual visits to the stations selected, but for several reasons this was not feasible at the time the tests were made. Where there was reasonable doubt an alternative scheme was selected. While the best route to each station could be seen from the plane no trail could be marked nor could the bearings of various lines be obtained. These conditions tend to complicate the work of station preparation parties. During the season of 1929 the areas covered by aeroplane reconnaissance will be checked by ground methods to test its reliability and to determine the revised methods of preparation to be adopted in conjunction with this method.

*Results Obtained.—*Twenty-two primary and 4 supplementary stations selected; axial length of nets, 190 miles; area covered, 4,400 square miles.

## PRIMARY TRIANGULATION IN EASTERN QUEBEC AND NEW BRUNSWICK

The year 1926 saw the completion of a large circuit of triangulation about 1,800 miles long composed of 1,300 miles of Canadian triangulation and 500 miles in the United States. The Canadian triangulation begins at Montreal, and extends down the St. Lawrence river, around the end of Gaspe, along Chaleur bay, south along the New Brunswick coast, thence west along the bay of Fundy.

In 1927 a commencement was made in cutting up this large loop by cross nets, the first being across the Gaspe peninsula from the St. Lawrence river to Chaleur bay by way of the Matapedia valley. From the head of Chaleur bay another cross net was projected southwest across the province of New Brunswick to meet a net which had been run north from Passamaquoddy bay to the St. John river.

In 1928 the Matapedia valley net was completed as well as a large part of the second net across the province of New Brunswick.

*Results Obtained.*—*Reconnaissance*: 10 primary and 1 intersection stations selected; axial length of net, 105 miles. *Station Preparation*: 17 stations prepared and permanently marked, at 6 of which towers ranging in height from 20 to 45 feet were built; axial length of net, 136 miles. *Angular Measurements*: 14 primary and 3 intersection stations completed; axial length of net, 120 miles; area covered, 3,700 square miles. *Zenith Distances*: These were observed and reduced to obtain the elevations of Matapedia Valley triangulation stations.

The operations in the Matapedia valley and across northern New Brunswick were carried on by two angular measurement parties, to each of which was attached a sub-party which moved ahead and set the electric signal lamps. The reconnaissance was carried on by the District Engineer in addition to his other duties. A separate party built the necessary towers and prepared stations for the angular measurement party.

Most of the stations were situated in the woods and were from eight to thirty miles distant from the nearest motor roads, so that considerable time was employed in transportation. Weather conditions were not favourable owing to the heavy precipitation over the area.

The triangulation covering the valley of the Matapedia river was completed in July 1928. With the completion of this net the Gaspe peninsula is covered with primary control to the extent that no point therein is further than 40 miles from a primary station.

In order that the province of New Brunswick should be equally well provided with primary geodetic control, it was decided to extend a triangulation net from Campbellton, New Brunswick, southerly and westerly to connect in the vicinity of Lawrenceville, N.B., with a net observed in 1917, which extends northerly from the bay of Fundy. The reconnaissance for the new net, which is approximately 100 miles in length was carried out during the present year, and it is intended to complete the angular measurements of this net in 1929. When this has been done this province will have an accurate triangulation covering its perimeter and the interior areas can be suitably provided with secondary triangulation and traverses as demands arise.

The work of station preparation was begun at a point of the Matapedia valley triangulation about 40 miles south of the St. Lawrence river and was continued southward to Lawrenceville, N.B. Each station was marked with a bronze tablet set in the centre of the top of a concrete monument.

Angular measurements were made at stations between lake Matapedia and the line Quisibis—Bald Peak in New Brunswick. As the elevations of many of the hills were unknown, particular attention was paid to determining them. This was done by running a line of precise levels to the triangulation station at Mont Joli, Quebec, which was used as a basic point in determining

the elevations of the remaining stations, by means of observed zenith distances. These elevations are controlled by known elevations at Campbellton and West base (Charlo, N.B.). A least squares adjustment has been made to remove the discrepancies in the field observations. The elevations refer to the bronze tablets in the monuments used to mark the triangulation stations. A tabulation of the resulting final elevations above sea-level of the triangulation stations follows:—

Mont Joli.....	521 feet	Ste. Florence.....	1,517 feet
Padoue.....	1,033 "	Laver.....	2,101 "
Sandy Bay.....	591 "	Assem.....	1,783 "
St. Moise.....	1,338 "	Mann.....	1,567 "
Comis.....	1,880 "	Squaw Cap.....	1,585 "
Val Marie.....	2,970 "	Campbellton.....	929 "
Castor.....	2,304 "	Matapedia.....	2,149 "
Barbeau.....	1,660 "	West Base (Charlo).....	74 "

Campbellton station, formerly occupied as a latitude and longitude station, is situated on a prominent spur of rock immediately adjoining the town of that name. As the original monument marking the station was found to have deteriorated, it was repaired, and as it is quite prominent and close to the town, a bronze plate giving its latitude, longitude, elevation, and the azimuth of a line to a neighbouring church spire was set in the top surface, so that this information will be immediately available to anyone wishing to make use of it.

Two theodolites of the new type, already referred to on page 11, were used throughout the work. It is noteworthy that no difficulty was experienced when using this instrument on frosty nights due to seizing of various parts, a source of trouble on many occasions with theodolites of the old type.

## GEODETIC ASTRONOMY STANDARDS AND ISOSTASY

### GEODETIC ASTRONOMY

During the field season of 1928 the work in geodetic astronomy consisted in making observations for longitude azimuth and latitude (Laplace determinations) at six stations of the Alberta primary triangulation, and for latitude and longitude at twelve primary triangulation stations in Ontario and Quebec, these latter being particularly for use in the study of isostasy. The observations were made by two astronomical field parties, each of which was equipped with an astronomical transit of the broken telescope type and a wireless receiving set.

This type of astronomical transit is giving the greatest satisfaction. A first consideration in deciding upon the suitability of an instrument for precise observations of any kind is the degree of accuracy that may be obtained by its use. The probable errors of the longitude and latitude observations made with the new instrument are smaller than have been secured from observations with the type of astronomical transit previously used; not only are the discrepancies among different nights smaller; the residuals of the several stars used in time determinations are also less than in the results with the other transits. In addition, the smaller weight of the new instrument renders it ideal for field operations. The employment of the wireless method of longitude determinations enables the engineer to make his observations at any survey station irrespective of its distance from wire lines. Formerly when the telegraph method of longitude was used it was necessary to select the stations for observing in close proximity to a telegraph line.

The stations occupied in the Alberta triangulation net were Brooks, about half way between Medicine Hat and Calgary; Spy Hill, twelve miles west of Calgary; Innisfail, half way between Calgary and Edmonton; Edmonton, just south of the city of Edmonton; Lavoy, about seventy miles east of Edmonton;

and Blackfoot, ten miles west of Lloydminster. The astronomical azimuth and longitude combined with the geodetic azimuth and longitude in the Laplace equation control the twist of the triangulation.

The astronomical observations made in Ontario and Quebec were at Maxville, Rigaud, Stayner (East Base) and Tiny in Ontario; and at Covey Hill, McDiarmid, Fairfax, Paquette, Garthby Church, L'Islet Base, Tortue (N. Base) and Beauport in Quebec.

### STANDARDS AND BASE LINES

The fifty metre invar tapes used on base line and precise traverse measurement were standardized before and at the end of the season's work. Nickel bar No. 10239 is the reference bar of all lengths of the Geodetic Survey of Canada. This metre bar was first obtained by this Survey in 1913. Its length as certified in 1913 by the National Physical Laboratory at Teddington, England, was  $1^m + 26\mu\cdot 9$ . In 1918, it was taken to Washington and the length as certified by the United States Bureau of Standards was  $1^m + 25\mu\cdot 8$ , a shortening of  $1\mu\cdot 1$ . In 1924, advantage was taken of a trip to London, England, by Mr. Field of the Topographical Survey's Laboratory to have that laboratory's bar again referred to the bar at Teddington. Another bar of 43 per cent nickel, No. 10241, was sent to the National Physical Laboratory with Mr. Field. This bar, No. 10241, was compared carefully with No. 10239 both before and after the trip to London and the measurements showed that there was complete agreement in their relative lengths both before and after the journey. The length of No. 10239 as relatively determined was  $1^m + 26\mu\cdot 3$  nearly the mean of the former values. Again during the past year these two bars, No. 10239 and No. 10241, were compared and their lengths have remained relatively constant. The length of the nickel bar No. 10239 used in the deductions of the lengths of the field tapes is now taken as  $1^m + 26\mu\cdot 3$ .

The invar tapes still give no indications of keeping fixed lengths, neither do they obey any fixed law in their behaviour. The changes while not large are yet of such dimensions that frequent standardization is very essential.

One base line near Senneterre, P.Q., was measured. This base line will control the scale of lengths in the triangulation of northern Quebec.

### ISOSTASY

Comparisons of the longitudes and latitudes of points on the surface of the earth, as determined by astronomical observations, and by triangulation from some other geodetic point show large discrepancies. An examination of the topography surrounding these stations indicates that there is some relation between the size of these discrepancies and the nature of the topography. For example, on a plain close to high rugged mountains the discrepancy (deflection of the plumb line) is generally large; also along the sea shore one generally finds large deflections. At Tadoussac on the north shore of the St. Lawrence river the deflection of the vertical causes an error in the astronomical position of 743 feet in a southeasterly direction, while at Father Point across the river and forty or fifty miles east, the deflection of the vertical causes an error of 1,089 feet in a northwesterly direction. However, if the effect on the deflection of the plumb line of the topography on the earth's surface surrounding an observation station is computed it will generally be found to be larger than the deflection itself; or in other words, if the deflection of the vertical is corrected for topography, the residual will be of the opposite sign. This led to the idea that beneath a mass on the earth's surface there must be a compensating deficiency of density of the mass beneath the surface of the earth. To this idea of the deficiency of mass below the surface partly counter-balancing the effect of the topography has

been given the name "Isostasy". It may be defined as the condition of the earth's outer crust and has been supported by analyzing the results of geodetic surveys. A study of the results obtained by measuring degrees of latitude and longitude by astronomical observations and by triangulation indicates that there are variations in the density of the material forming the outer portion of the earth with the materials of least density under the highest mountains.

This condition of "Isostasy" was first mentioned definitely by E. B. Airy and J. H. Pratt, English scientists, about seventy-five years ago, when they were studying the results from the Geodetic Survey of India. In later years Professor Hayford and Dr. Wm. Bowie of the United States Coast and Geodetic Survey have made great progress in the development of the theory of Isostasy. Also this theory of Isostasy as defined by Hayford and Bowie has been applied by the survey of India to solve many problems connected with the discrepancies that appeared there. The Himalaya mountains, the highest in the world, naturally produced the largest discrepancies between astronomical and geodetic values of longitude and latitude.

Canada with its immense territory and rugged topography along the coast and its wide rolling interior plains offers a splendid field for isostatic research. The information for such a study is procured at very little expense. Already observations at over a hundred stations have been made and reliable information is being deduced as a result of its study.

## LEVELLING

### OFFICE OPERATIONS

During the year the general revision of the records of precise levelling bench marks has been continued. These records are being issued in nine publications. One of these deals with the Maritime provinces, two are for Quebec, two for Ontario and one for each of the western provinces. The first three publications have already been issued, while those dealing with Ontario are now in the press. The material for the remaining provinces has nearly all been assembled and it is expected all the publications will have been issued in 1929.

Facing this page will be found the index map of Publication No. 19, Precise Levelling in Ontario, South of Parry Sound. Contrary to the usual practice of indicating the lines of levels by continuous red lines, on this map the approximate location of each bench mark has been denoted by a red dot. By this method an idea of the relative number of bench marks in any locality may be ascertained.

The records of elevations, compiled from the profiles of the various railways, have steadily increased. During the year 94 rolls of profiles, covering 1,875 miles of railway, were collected and bring the total up to 576 rolls and 12,650 miles. About 8,900 miles of railway level results have now been compiled, adjusted to the datum of mean sea level and typed in a form convenient for reference. These lists include about 30,000 elevations.

Many inquiries from other departments and from outside sources for information regarding elevations, have been dealt with. These inquiries indicate that the extension of lines of levels in the field will be of practical service to the engineering public and others.

Some attention has been given to the information regarding elevations contained in guides, directories and annuals published by outside organizations. Such publications, when the altitudes have been placed on standard datum, afford a very economical channel for the dissemination of this useful information.

## FIELD OPERATIONS

The field operations in the summer of 1928 were about equally divided between precise and secondary levelling, one party being engaged entirely on precise levelling in British Columbia, one on secondary levelling in Ontario and another, operating in Quebec and Ontario, being engaged partly on each kind of work. In addition to the three regular parties there were two special parties, one being engaged in inspection of precise level bench marks throughout the season, the other on inspection for the first part of the season and fundamental bench mark construction for the latter part.

### LEVELLING IN BRITISH COLUMBIA

The work of the party engaged in British Columbia lay wholly along the Pacific Great Eastern railway and resulted in the completion of the whole line from Squamish to Prince George, of which the first 84 miles had been levelled the previous fall. At Clinton a connection was made with the line of levels along the Cariboo road from Ashcroft which had also been run the previous season.

### LEVELLING IN QUEBEC

Starting at Hull, precise levels were extended along the Waltham branch line of the Canadian Pacific railway to its terminus at the above village and thence continued along the provincial highway a further distance of ten miles to the village of Chapeau, on Allumette island. Returning to Maryland station, on the Canadian Pacific railway, levels were carried southerly along country roads to the Ottawa River shore at Norway Bay, thence a branch was run easterly along the Canadian National railway to the bridge over the river above Chats Falls, while the main line of levels was carried westerly along the same railway through Portage-du-Fort and across the Ottawa River bridge into the province of Ontario.

The above levelling resulted in the establishment of an adequate number of bench marks along the north shore of the Ottawa river for the first hundred miles above Ottawa, including lake Deschenes, Chats falls, Chats lake, the rapids at Portage-du-Fort and the channel between Allumette island and the Quebec mainland. These operations were in response to the demand for vertical control required in the investigation of this area for hydro-electric developments.

### LEVELLING IN ONTARIO

Entering the province of Ontario at the Canadian National Railway bridge over the Ottawa river above Portage-du-Fort, P.Q., the precise levelling party which had spent the first part of the season in Quebec continued operations westerly along the main line of the railway to Pembroke and from this point southerly along the Pembroke-Golden Lake branch to Golden Lake station, where a junction was effected with the Ottawa-Depot Harbour precise level line, run several years ago. A fundamental bench mark was constructed in the town of Pembroke.

Westerly from Pembroke secondary levels were run to Deux Rivieres, following the Pembroke-North Bay road as far as the crossing under the Canadian Pacific railway, a little east of Ashport; from this point the levels followed the railway owing to the unusually hilly character of the road. Branches were run to the shore of the river, for the purpose of establishing bench marks, at Petawawa, Joachim rapids, Rocher Capitaine rapids and Deux Rivieres rapids. The field work of this party was closed for the season near the latter point.

A second party spent the complete season in secondary levelling in western Ontario, starting at Sarnia and following the "Blue Water" highway through Goderich, Kincardine, Southampton, Owen Sound, Meaford, Collingwood, Penetang and Midland. At each end and at four or five intermediate points the line intersected precise lines of the Western Ontario net. From a point near Parkhead, between Southampton and Owen Sound, a branch was run northerly the full length of the Bruce peninsula to Tobermory. Throughout the season's work special care was taken to secure bench marks at all places having wharves or harbours on the shore of lake Huron, in some instances bench marks being established directly in the concrete work of the wharves.

#### LEVELLING IN SASKATCHEWAN AND ALBERTA

A special party consisting of an engineer and one assistant constructed fundamental bench marks in certain cities and towns in the above provinces.\* The monuments—fourteen in all—were constructed at the following places in Alberta: Calgary, Coronation, Edmonton, Hanna, Lethbridge, Macleod, Medicine Hat, Red Deer, Vermilion and Wainwright. In Saskatchewan they were constructed at Maple Creek, North Battleford, Swift Current and Unity.

The actual construction, in accordance with previous practice, was carried out in each place by contract or by day labour, employed locally. All the monuments were constructed in places through which precise levels had previously been run, so no major levelling operations were involved in determining their elevations; however, the recovery of the old levels and the careful levelling to each monument required quite an appreciable amount of instrumental work in the course of the summer. This was carried out by the engineer and his assistant, together with local help, during and after the construction of each monument, as opportunity offered.

This party also established nineteen standard bench marks in buildings of a permanent nature which have been erected in these towns since the original levelling was carried out. For transportation and for carrying instruments, tools, etc., a touring car was used.

#### INSPECTION OF BENCH MARKS

The country-wide inspection of precise level bench marks, inaugurated in 1924, at the Atlantic coast, was completed at the Pacific coast during the 1928 season, in time for the revised descriptions of all bench marks to be used in the series of publications then in course of preparation. A special inspection party, consisting of an engineer and one railway employee, spent the whole field season inspecting bench marks in Saskatchewan, Alberta and eastern British Columbia, travelling on a railway motor car and securing living accommodation at hotels and boarding houses along the lines inspected. The lines inspected by the special party aggregated 4,970 miles in length and entailed travelling by railway motor car a distance of 7,000 miles. In addition to the work of this party the engineer in charge of fundamental pier construction inspected five lines, aggregating 1,670 miles in length, in the earlier part of the season; the Supervisor of Levelling inspected all bench marks in the city of Vancouver and surrounding district and also certain other British Columbia lines. In all, the year's inspection included 2,267 bench marks, of which 199, or 9 per cent, were destroyed or could not be found by the inspector.

\* A full description of the fundamental bench marks and the principles guiding their location will be found in the Annual Report of the Director, Survey of Canada for 1925-26.

The following is a detailed statement of the levelling run in 1928:—

Line	On railway	Off railway	Total
	Miles	Miles	Miles
<i>Precise Levelling—</i>			
Hull to Chapeau, Que.....	78.2	11.2	89.4
Maryland, Que. to Golden Lake, Ont.....	70.5	10.6	81.1
D'Arcy to Quesnel, B.C.....	265.3	4.6	269.9
Battleford and North Battleford, Sask.....	0.0	7.6	7.6
	414.0	34.0	448.0
<i>Secondary Levelling—</i>			
Pembroke to Deux Rivieres, Ont.....	30.3	47.5	77.8
Sarnia to Midland, Ont.....	0.0	257.5	257.5
Parkhead to Tobermory, Ont.....	0.0	68.2	68.2
	30.3	373.2	403.5

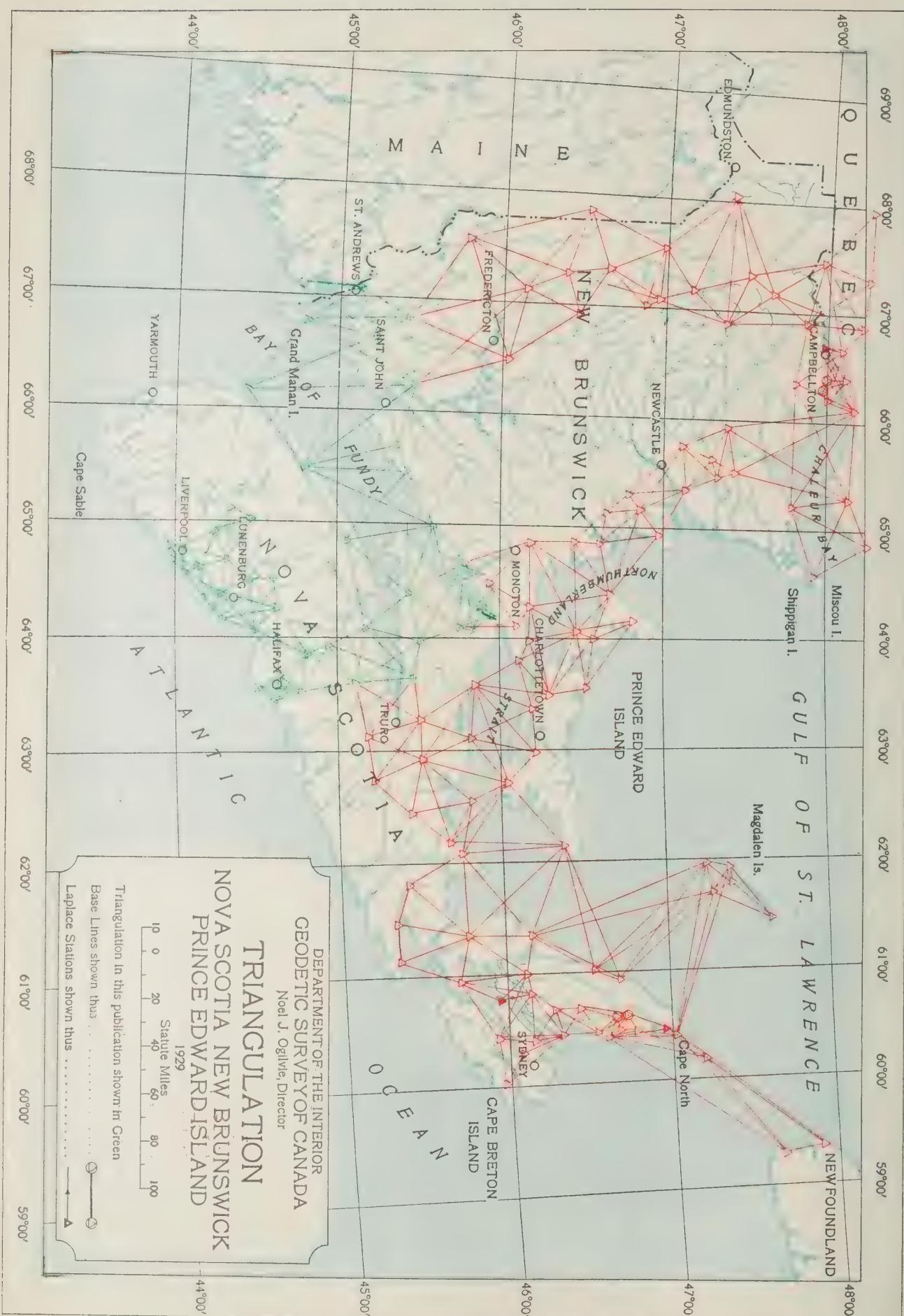
#### SUMMARY BY PROVINCES FOR 1928

Province	Mileage Levelled	B.M. Piers Built	Total B.M.'s. Established
<i>Precise Levelling—</i>			
Quebec.....	119	7	91
Ontario.....	51	1	30
Saskatchewan.....	8	4	17
Alberta.....	0	10	17
British Columbia.....	270	61	94
	448	83	249
<i>Secondary Levelling—</i>			
Ontario.....	403	19	195

The mileage of precise and secondary levelling in each of the provinces is as follows:—

Province	Precise Levelling			Secondary Levelling		
	Prior to 1928	1928	Total	Prior to 1928	1928	Total
Nova Scotia.....	729	.....	729	.....	.....	.....
New Brunswick.....	1,096	.....	1,096	.....	.....	.....
Quebec.....	3,065	119	3,184	169	.....	169
Ontario.....	5,689	51	5,740	.....	403	403
Manitoba.....	2,263	.....	2,263	368	.....	368
Saskatchewan.....	4,105	8	4,113	5,098	.....	5,098
Alberta.....	2,866	.....	2,866	3,795	.....	3,795
British Columbia.....	3,009	270	3,279	.....	.....	.....
Yukon.....	458	.....	458	.....	.....	.....
Minnesota, U.S.A.....	89	.....	89	.....	.....	.....
Vermont, U.S.A.....	6	.....	6	.....	.....	.....
	23,375	448	23,823	9,430	403	9,833





The mileage of *precise* levelling along each of the railways is as follows:—

Railway	Miles	Railway	Miles
Canadian National.....	11,631	New York Central.....	55
Canadian Pacific.....	7,522	Pere Marquette.....	55
Kettle Valley.....	364	Maine Central.....	36
Pacific Great Eastern.....	357	Roberval and Saguenay.....	31
Timiskaming and Northern Ontario.....	320	Napierville Junction.....	28
Algoma Central.....	319	British Columbia Electric.....	28
Alberta and Great Waterways.....	282	Quebec Railway, Light and Power Co.....	25
Great Northern.....	230	London and Port Stanley.....	24
Edmonton, Dunvegan and British Columbia.....	170	Alma and Jonquiere.....	16
Quebec Central.....	149	Maritime Coal, Railway and Power Co.....	12
Dominion Atlantic.....	146	Michigan Central.....	3
White Pass and Yukon.....	91	Highways and cross-country levels.....	1,847
Temiscouata.....	82		
			23,823

## TRIANGULATION ADJUSTMENTS

A complete revision of the geographic co-ordinates of the triangulation east of Montreal covering the St. Lawrence River area and the Maritime Provinces has been necessitated by the junction of two systems of triangulation near Amherst, N.S.

At the junction of two systems two values of the co-ordinates will exist for the junction point, a different value resulting from each of the systems joined. The purpose of the revision is to eliminate the confusion arising from double values at this point of closure.

The combined system for closure elimination consists of five continuous nets of triangulation, each complete in itself with regard to controls in length and Laplace stations. These were adjusted as units, as the field work progressed. In order to utilize this work definite positions for the termini of each net are required to be known.

The positions of the termini are obtained from a least square solution in which the triangulation is replaced by the strongest chain of triangles. The angles of the triangles are the adjusted angles as obtained from the net adjustments. Angle equations are formed with zero absolute terms and combined with latitude and longitude equations to form a solution which will eliminate the closure.

With the resulting corrections known, latitude and longitude equations may be written for each set of terminal points which will give the amount of change in geographic position. Thus the positions of the termini are obtained.

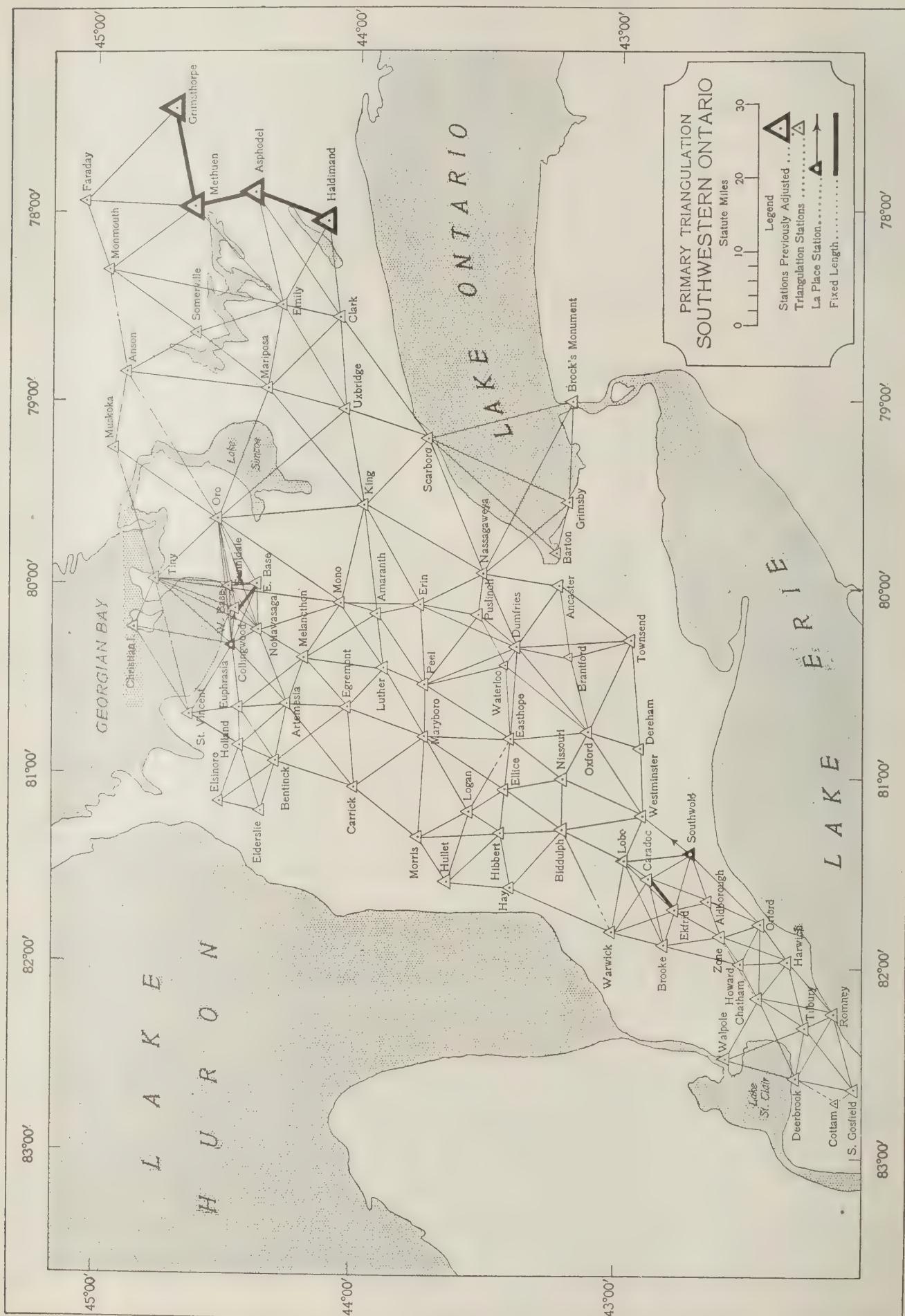
Each net is now adjusted in its entirety so as to bring each terminal to its desired position.

The above revision is completed for four of the nets. Of the remaining one but very little remains to be done. It is the intention to utilize the revised position of this loop as a framework for other loops in the Maritimes.

Geodetic data have been supplied to federal and provincial survey bureaux, as requested, to aid in the control of local surveys or in the compilation of maps.

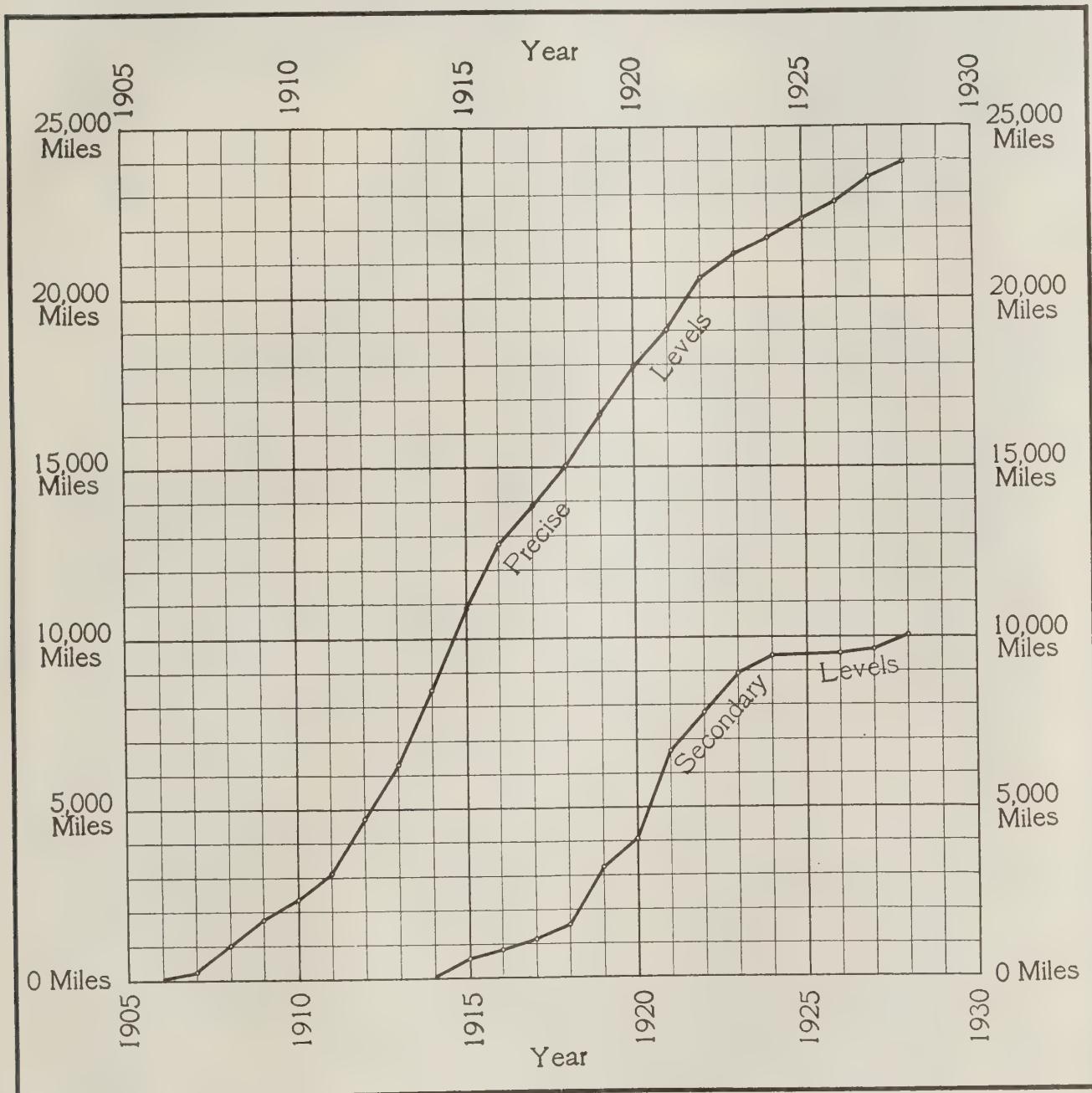
A publication comprising the triangulation in the Bay of Fundy area with an extension from near Truro to Halifax, thence along the coast of Liverpool, N.S., is in course of preparation. See map facing this page.

A publication comprising the triangulation in western Ontario is being prepared. This net is illustrated on page 24.



## PRECISE LEVELLING ADJUSTMENTS

The work of the adjustment of precise levelling for the year consisted chiefly in obtaining the best adjusted elevations of all junction points on the precise level net and from these the adjusted elevations of all bench marks on these lines. The adjustment is now composed of ninety-four conditions adjusted in such a way as to constitute a whole net adjustment.



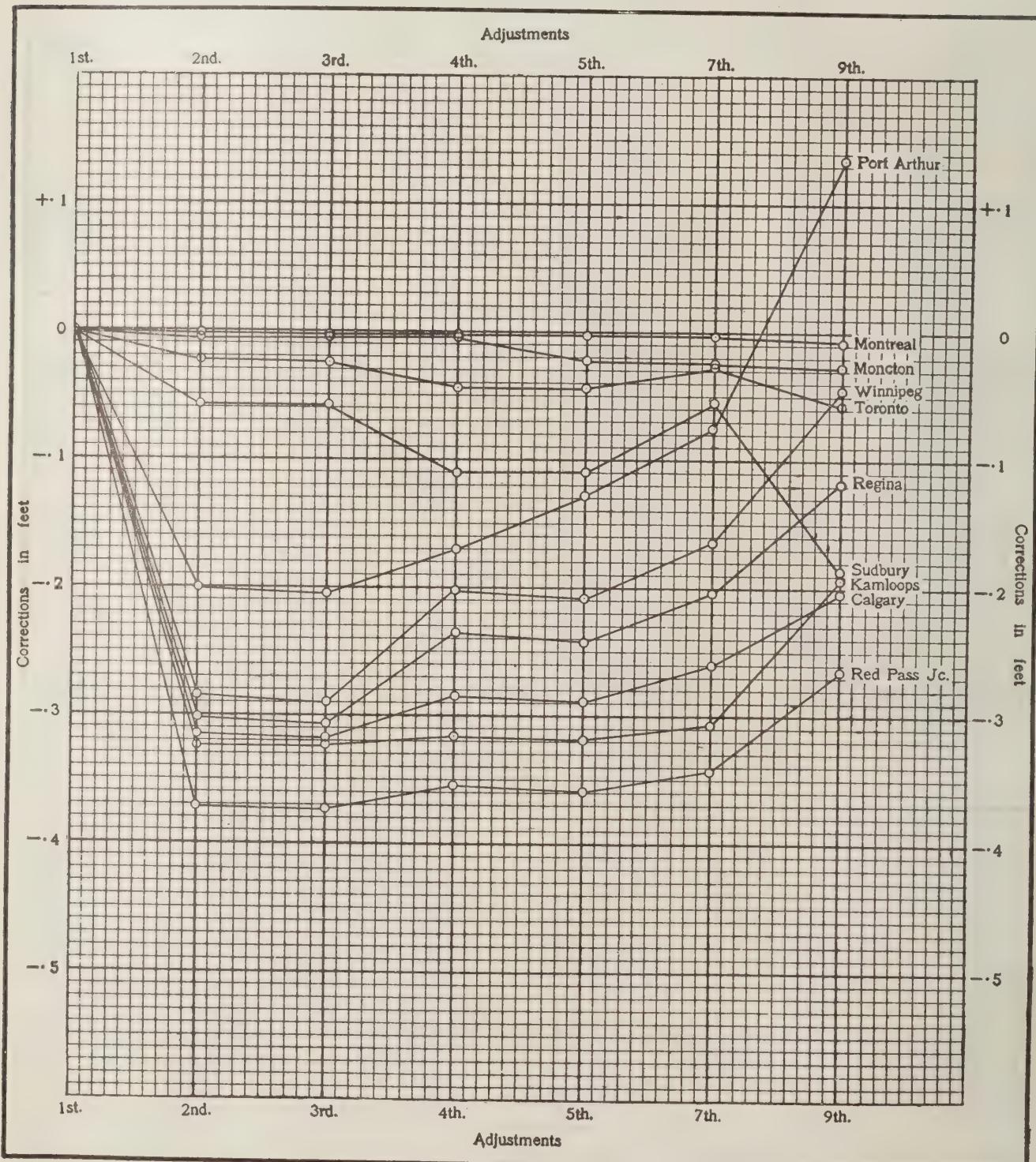
The probable errors showed the work to be highly satisfactory. Particular attention was given to the values of sea-level at various tidal stations on the Atlantic and Pacific seaboards in the endeavour to ascertain if any evidence of a difference of sea level exists. The closures of all circuits in which tidal points were involved were such as to lead to the belief that there is no variation of this nature.

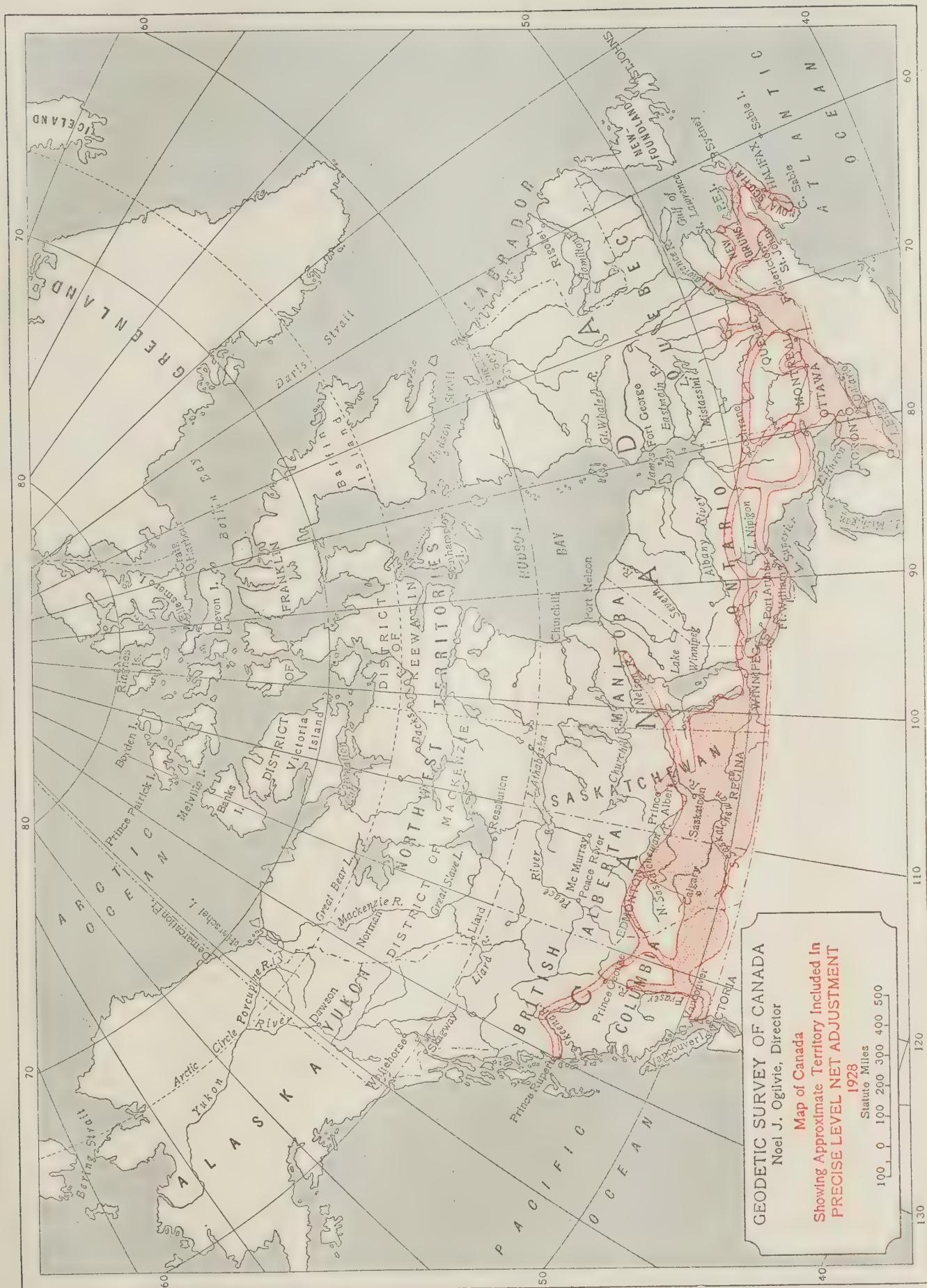
The question of applying the orthometric correction to differences of levels of points on the Great Lakes came up. To be consistent in taking into account the orthometric correction, this correction should be applied in lake levels as was done in all cases of lines on land. On the other hand it is in general considered that all points on the same body of water even of such dimensions as

the Great lakes are at the same elevation. It was, therefore, decided to obtain two elevations for all junction points on the net, one set resulting from the orthometric elevation being applied to lake levels, and the other from considering all points on the lakes as at the same level. The former values of elevations for the junction bench marks are contained in Geodetic Survey of Canada Publication No. 28, "The Adjustment of the Precise Level Net of Canada, 1928." The latter values are used for all bench marks in the Geodetic Survey of Canada Publications Nos. 16 to 24 "Precise Levelling."

The points connected by lake levels and the orthometric correction in each case are as follows:—

Kingston to Toronto on Lake Ontario.....	O.C. = + .0153
Goderich to Collingwood on lake Huron and Georgian bay.....	O.C. = - .0334
Collingwood to Thessalon on Georgian bay.....	O.C. = - .1087
Gros Cap to Michipicoten on lake Superior.....	O.C. = - .0840
Michipicoten to Port Arthur on lake Superior.....	O.C. = - .0266
Kootenay Landing to Procter on Kootenay lake.....	O.C. = - .0621







## MATHEMATICAL RESEARCH

The Mathematical Research Division has completed the solution of several problems arising from the use of precise traverse as a control survey in Canada.

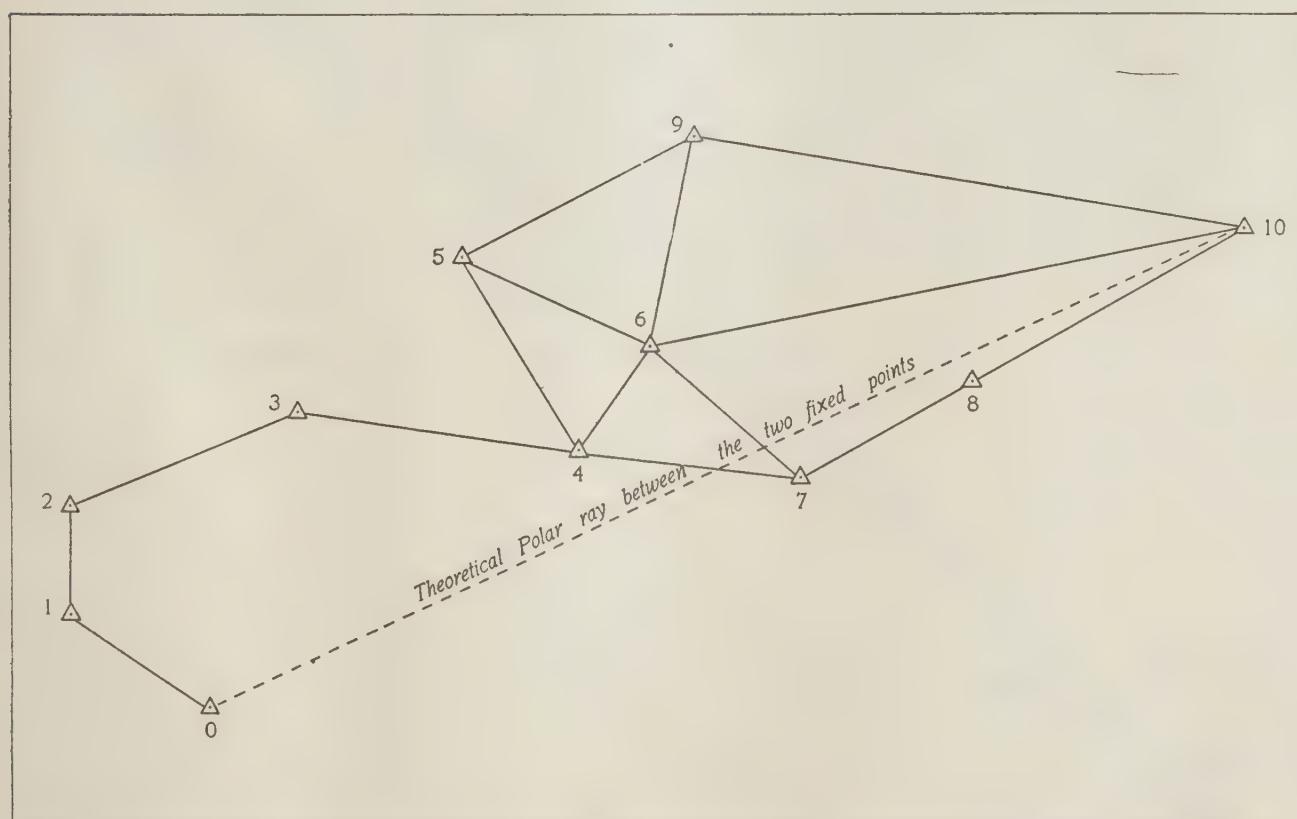
When geodetic control is extended from one area to another in a country as large as Canada, mathematical complexities arise due to the survey progressing by a circuitous route and returning to a point already established somewhere in that system. This is known as a loop closure and introduces the mathematical condition that the latitude and longitude of this point computed through the return system of survey must be the same as that previously determined.

Or a system of survey may be extended to join two points fixed by a previous survey of a higher order of accuracy. This may also be regarded as a loop closure. In either case, the system of survey may be composed of all triangulation, all precise traverse or alternate sections of traverse and triangulation.

Due to the introduction of precise traverse for the purpose of geodetic control alternating with triangulation in some sections of Canada the problem of adjusting loops composed of part triangulation and part precise traverse has presented itself.

A large loop of this nature is now being completed in British Columbia, and another is partly completed in Ontario.

The accompanying diagram illustrates a loop closure. The terminal points 0 and 10 are assumed fixed by a previous survey of a higher order accuracy. Hence, any adjustment of the survey shown between them must not change the latitude and longitude of these points.



The connecting survey, composed of precise traverse from 0 to 4 and of triangulation from 4 to 10 must receive a least squares adjustment to minimize the errors of observation and to attain the greatest possible accuracy from the labour and money expended in the field work.

As the works on geodesy and least squares adjustments now available do not deal with this problem in any respect, research work has been carried on in this office and a method of simultaneous adjustment has been evolved, the manuscript of which is now being prepared for the printer.

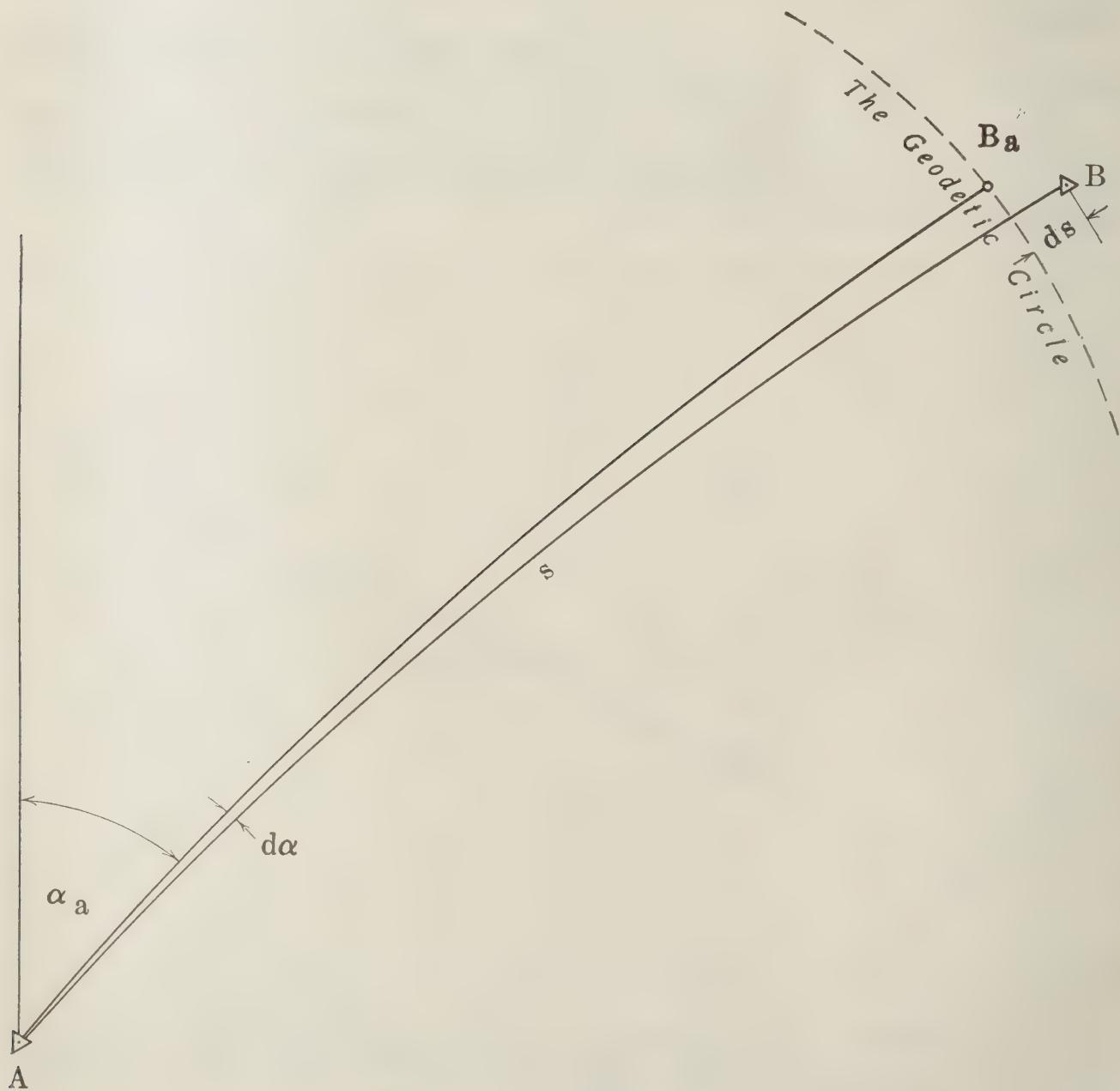
Research work has also been conducted to find a method of solution by parts for the evolution of geodetic positions over long lines.

A new trial line method has also been evolved for the solution of the inverse problem.

The facility with which the terminal geodetic position of long lines may be evaluated by a solution in parts is also an important advantage in the solution of the inverse problem over long lines.

Even for the longest lines encountered an approximate inverse solution may be made by the methods of spherical trigonometry regarding the earth as a sphere. A closer approximation may, however, be effected by the use of geodetic formulae for lines under 100 miles in length.

An approximate solution by either method gives the values  $\alpha_a$  and  $s_a$  of a trial line  $AB_a$ , the terminal point of which will not in all probability exactly coincide with the point B. Knowing, however, the position of the point A, one



may use this value of  $\alpha_a$  and  $s_a$  to work out a forward solution by parts and thereby find the exact position of the terminal  $B_a$  relative to the point  $B$ .

$$\begin{aligned} \text{Let } \varphi_B - \varphi_{B_a} &= \Delta \varphi " \\ \lambda_B - \lambda_{B_a} &= \Delta \lambda " \end{aligned}$$

It is seen that the line  $A-B_a$  of initial azimuth  $\alpha_a$  and length  $s_a$  may be rotated about the normal at  $A$ , through the small angle  $d\alpha$  and extended by  $ds$ , so that the terminal  $B_a$  will coincide with the point  $B$ . This procedure will bring about a change in the point  $B_a$  of  $\Delta \varphi "$  in latitude and of  $\Delta \lambda "$  in longitude.

The relationships between  $d\varphi$ ,  $d\lambda$ ,  $d\alpha$ , and  $ds$  are as follows:—

$$d\varphi = \frac{W \sin \alpha_2}{R_2} d\alpha,$$

$$d\lambda = \frac{W \cos \alpha_2}{W_2 \cos \varphi_2} d\alpha.$$

If the change in the reverse azimuth is required it may also be easily computed from the following equations:—

$$*W d\alpha_2 = + R_2 \sin \alpha_2 \frac{dW}{ds} - W_2 \cos \varphi_2 \cos \alpha_2 d\lambda_2$$

where

$$\frac{dW}{ds} = - \frac{W_1 \cos \varphi_1 \cos \alpha_1}{W_2 \cos \varphi_2 \cos \alpha_2} + \frac{W \tan \varphi_2}{W_2 \cos \alpha_2}$$

A further example of the application of this method has arisen in connection with the delimitation of that portion of the Ontario-Manitoba boundary between Island lake and Hudson bay. From the east extremity of Island lake, the position of which is to be determined astronomically, the boundary passes according to statute, along the geodetic line to the intersection of the shore line of Hudson bay with the 89th meridian of longitude. When the latter point has been located astronomically, and the latitude of the intersection determined, the inverse solution worked by this method will readily afford the initial azimuth on which to commence the actual determination of the line together with the distance between the two points.

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\*See "Geodesy" by W. M. Tobey, pages 49 to 56.

LOCALITY OF FIELD OPERATIONS OF THE GEODETIC SURVEY OF  
CANADA DURING THE FISCAL YEAR ENDED MARCH 31, 1929

TRIANGULATION

Northern British Columbia .....	Primary Triangulation—reconnaissance, angular measurements, station preparation.
Alberta and Saskatchewan .....	Primary Triangulation—reconnaissance, angular measurements, station preparation and tower building.
Northern Ontario .....	Primary Triangulation—reconnaissance, angular measurements, station preparation, tower building and precise traverse.
Northern Quebec .....	Primary Triangulation—reconnaissance, angular measurements, station preparation and tower building.
Gatineau Valley, Que. .....	Reconnaissance.
Matapedia Valley, Que., and Northwest New Brunswick .....	Primary Triangulation—reconnaissance, angular measurements, station preparation and tower building.

GEODETIC ASTRONOMY, ISOSTASY AND BASE LINES

Alberta .....	Laplace stations.
Eastern Ontario .....	Isostasy investigation.
Quebec .....	Isostasy.
Northern Quebec .....	Base line measurement.

LEVELLING

British Columbia .....	Precise levelling
Saskatchewan }	
Manitoba .....	Construction of fundamental bench marks.
Ontario .....	Precise and secondary levelling.
Quebec .....	Secondary levelling.

## LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

	CENTS
Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia—(Withdrawn as levelling contained is republished).	
Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec .....	10
Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.....	10
Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec—(Withdrawn, as levelling contained is republished).	
Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation .....	10
Instructions to Lightkeepers; Use of Electric Signal Lamps being an Appendix (No. 4) to Publication No. 5.....	10
Publication No. 6—(Withdrawn, as levelling contained is republished).	
Publication No. 7—Geodetic Position Evaluation.....	10
Publication No. 8—Field Instructions for Precise Levelling.....	10
Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning. (Out of print.)	
Publication No. 10—Instructions for Building Triangulation Towers.....	10
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Publication No. 12—Mathematical Statistics of the Geodetic Survey of London, Ont. (Distributed at London, Ont.)	
Publication No. 13—Errors of Astronomical Positions Due to Deflection of the Plumb Line. (Out of print.)	
Publication No. 14—Levelling, Co-ordination of Elevations of Bench Marks in the City of Calgary, Alberta .....	10
Publication No. 15—Levelling, Bench Marks Established along Meridians, Base Lines and Township Outlines in Saskatchewan.....	10
Publication No. 16—Levelling. Precise Levelling in Nova Scotia, New Brunswick and Prince Edward Island .....	10
Publication No. 17—Levelling. Precise Levelling in Quebec South of St. Lawrence river .....	10
Publication No. 18—Levelling. Precise Levelling in Quebec North of St. Lawrence river .....	10
Publication No. 19—Levelling. Precise Levelling in Ontario South of Parry Sound...	10
Publication No. 20—Levelling. Precise Levelling in Ontario North of Parry Sound...	10
Publication No. 21—Levelling. Precise Levelling in Manitoba .....	10
Publication No. 22—Levelling. Precise Levelling in Saskatchewan .....	10
Publication No. 23—Levelling. Precise Levelling in Alberta.....	10
Publication No. 24—Levelling. Precise Levelling in British Columbia.....	10
Publication No. 25—The Conversion of Latitudes and Departures of a Traverse to Geodetic Differences of Latitude and Longitude.....	25
Publication No. 26—(In preparation).	
Publication No. 27—(In preparation).	
Publication No. 28—Adjustment of Precise Level Net of Canada, 1928.....	10
Reports of the Operations of the Geodetic Survey of Canada, April 1912, to March, 1922, prepared by the Director for the First General Assembly of the International Geodetic and Geophysical Union held at Rome, 1922. (Bound with the Reports of the Section of Geodesy of the International Geodetic and Geophysical Union, 1922) .....	10
Report of the Operations of the Geodetic Survey of Canada, April, 1922, to March, 1924, prepared by the Director for the Second General Assembly of the International Geodetic and Geophysical Union held at Madrid, 1924.....	10
Report of the Operations of the Geodetic Survey of Canada, April, 1924, to December, 1926, prepared by the Director for the Third General Assembly of the International Geodetic and Geophysical Union held at Prague, 1927.....	10

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Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.....	10
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919 (Out of print).	
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920 (Out of print).	
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921 (Out of print).	
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Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1924.....	10
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1925.....	10
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1926.....	10
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1927.....	10
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1928.....	10
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1929.....	10

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Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Ottawa.

Department of the Interior  
GEODETIC SURVEY OF CANADA  
NOEL J. O. VIE, DIRECTOR  
MAP  
OF EASTERN CANADA  
SHOWING  
CONDITION OF FIELD OPERATIONS  
JULY 1928

1928

On 60 Miles

GENO

Triangulation Completed - Actual lines and stations not shown  
Triangulation in Progress  
Precise Traverse  
Precise Levelling  
Precise Traverse on  
Astronomic Station  
Laplace Station  
Base Line  
Tidal Station





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Department of the Interior  
GEODETIC SURVEY OF CANADA  
NOEL J. OGILVIE, DIRECTOR

WESTERN CANADA  
SHOWING  
CONDITION OF FIELD OPERATIONS

AT END OF YEAR  
1929

Scale 1:380,600 or 60 Miles to 1 inch

LEGEND

Triangulation Completed - Actual lines and stations not shown

Triangulation in Progress...

Precise Traverse...

Precise Levelling...

Precise Traverse and Levelling...

Astronomic Stations / Latitude...

Azimuth...

Replace Station...

Base Line...

Tidal Station



**Note:** Triangulation from Lake Superior to the 92<sup>nd</sup> Meridian and from the Meridian to the Pacific Coast and the United States Coast and Geodetic Survey as part of a coordinated system of triangulation. Boundary.

Prepared in  
Natural Resources Intelligence Service

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